

# VU Research Portal

## Efficient High Frequency Checkpointing for Recovery and Debugging

Vogt, D.

2019

### **document version**

Publisher's PDF, also known as Version of record

[Link to publication in VU Research Portal](#)

### **citation for published version (APA)**

Vogt, D. (2019). *Efficient High Frequency Checkpointing for Recovery and Debugging*. [PhD-Thesis - Research and graduation internal, Vrije Universiteit Amsterdam].

### **General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal ?

### **Take down policy**

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

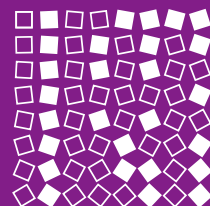
### **E-mail address:**

[vuresearchportal.ub@vu.nl](mailto:vuresearchportal.ub@vu.nl)

# Efficient High Frequency Checkpointing for Recovery and Debugging

Computers and their software play an ever increasing role in our daily life—software runs on our computers, phones, TVs and around our wrists in the form of smart watches. While one can argue that software has improved our quality of life in many ways, it is also plagued by a problem, which is as old as software itself: Reliable software is hard to build. “Have you tried turning it off and on again”, has become our pop-culture’s iconic manifestation of this problem. Checkpointing is an important technique that has many applications inside the reliability domain, such as automated error recovery and debugging. An integral part of checkpointing is taking a snapshot of a process’ memory, also known as memory checkpointing, which is the main subject of this thesis.

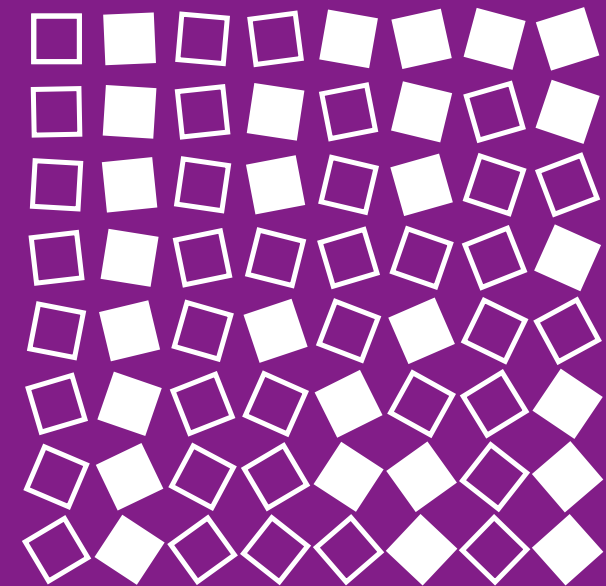
In particular this thesis concentrates on scenarios that require high checkpointing frequencies, which is often the case for automated error recovery techniques and debugging. We demonstrate the need for specialized high frequency memory checkpointing techniques and propose enhancements to current checkpointing techniques to make them fit for such use cases. Further, we explore the deployability trade-offs of different checkpointing techniques. We show that if the target application can be recompiled, pure userland techniques relying on compiler-instrumentation can offer a significantly better run-time performance than their page-granular counterparts without losing memory guarantees. Further, we show that speculation and exporting copy-on-write functionality as a first-level kernel primitive to the userland lowers the overhead of page granular checkpointing significantly. Finally, we examine techniques that can efficiently store and search the large amounts of checkpointed data resulting from the high checkpoint frequency. We then incorporate these techniques in Delorean, the first time traveling debugging system on top of high-frequency checkpointing. We hope that the techniques and tools developed in this thesis will facilitate the development of reliable software.



Efficient High Frequency Checkpointing for Recovery and Debugging

Dirk Vogt

# Efficient High Frequency Checkpointing for Recovery and Debugging



Dirk Vogt

ISBN 9789402813883



9 789402 813883